COMM.NET.200 Computer Networking I
Remote laboratory exercise

# Remote laboratory exercise
# Version 2023-06-07

# Contents

# 1 Introduction

In this laboratory exercise you will set up a small communications network using the network simulator GNS3. You will be setting up routers, switches and Linux hosts.

You should follow the instructions given in this paper in order and compile a report from the answers in PDF format. Short answers with some key points are enough. In addition, save the configurations of all devices used (7 pcs) as either text files or screenshots, and submit them together with the report.

# 2 OpenVPN

You need an OpenVPN connection to use the remote server located at the university. Instructions on how to establish the connection can be found on the course Moodle page.

# 3 GNS3 settings

When starting GNS3 for the first time, you should set up the remote server parameters in the setup wizard as shown in Figure 1. You can also find the setup wizard from the menu: *Help -> Setup Wizard*.

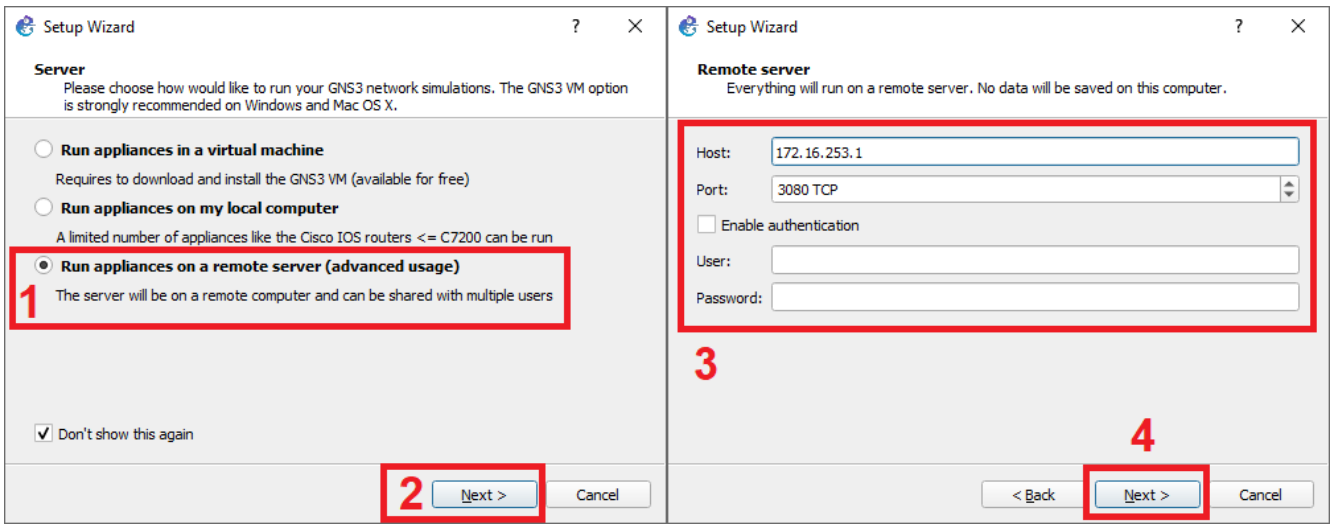


Figure 1: Remote server settings. Click Finish on the following page.

# 4 GNS3 overview

This section will give a brief overview of the GNS3 user interface. Start with creating a blank project and give it a name (e.g. your student number).

Note that GNS3 does not yet support user separation, so currently anyone can see and edit all projects. Please do not mess with anyone else's projects, thank you. We trust in you. You can take a backup of the configurations in case you cannot finish the exercise in one sitting. **Configurations will also disappear if you close the project or shutdown the virtual devices without explicitly saving the configurations beforehand.** More detailed instructions on how to save the configurations can be found in chapter 8.

Figure 2 below highlights the main features we will use in this exercise.

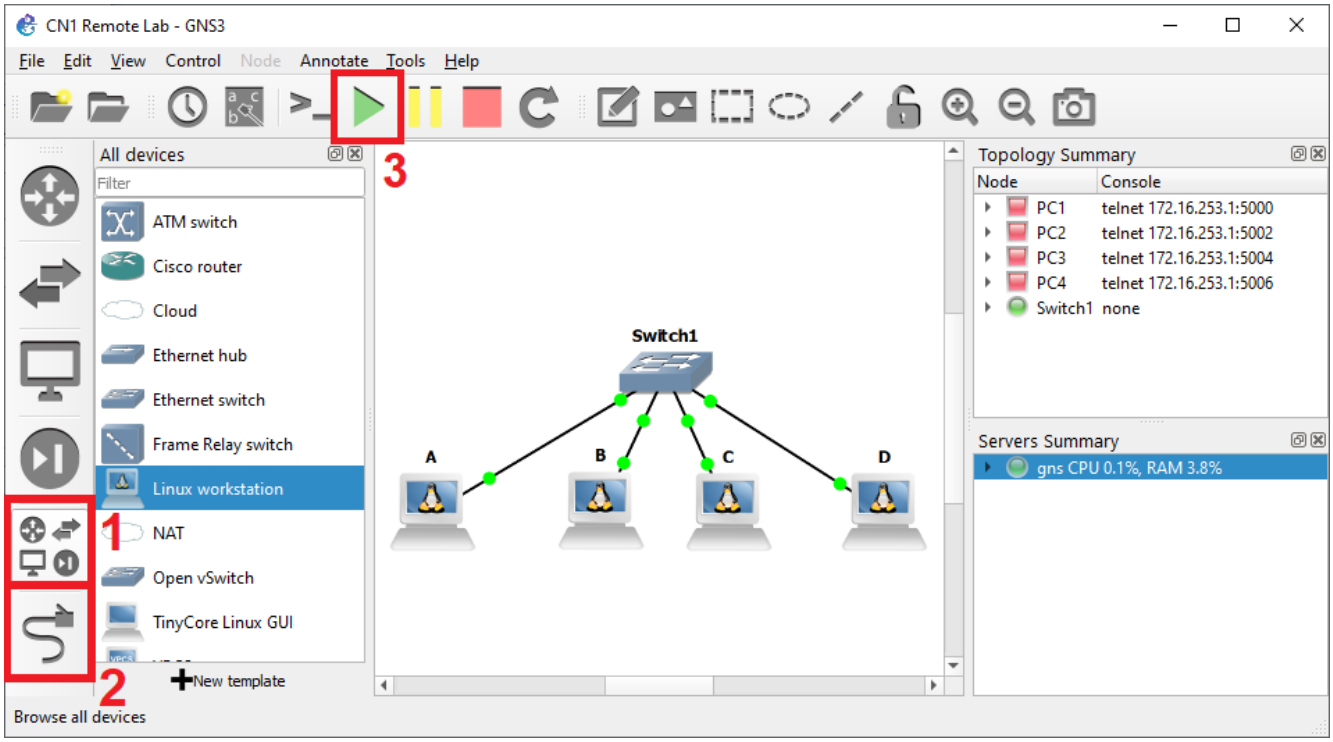


Figure 2: GNS3 user interface with the important features highlighted

In this exercise we will mainly use the following features:

1. Show the list of all virtual devices you can add to the project.
2. Creates a link between two devices, i.e., connects a virtual cable between them.
3. Turn on all virtual devices.

Additionally, on the right side you can see a list of all devices which have been added to the project.

Right-clicking a device either in the list or workspace brings up a context menu with useful commands.

# 5 Switching

In this task, you will create a basic local area network where all of the workstations will be directly reachable via a switch.

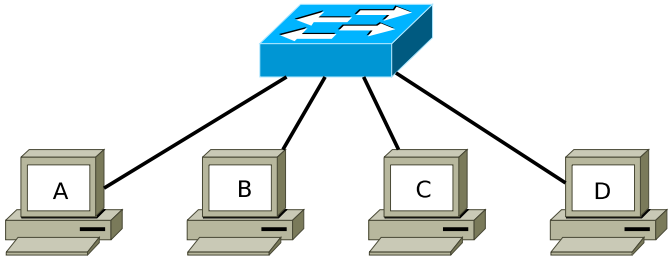


Figure 3: Network topology

Open the list of all available devices (figure 2, button 1) and add one *Ethernet switch* and four *Linux workstations* to the workspace. You can rename the workstations by double-clicking the name or choosing *Change hostname* from the context menu.

Next, connect all workstations to the switch using a virtual cable (figure 2, button 2). The workstations only have one network interface (*eth0*), so you should use that. By default, the switch has 8 ports and you can use any of them.

At this point your network should look like the one in Figure 2. Start up all devices with the green play button (figure 2, button 3).

Next, let's set up IP addresses for the computers' *eth0* interfaces. You should use the address range 10.0.X.0/24, where X is the last digit of your student number.

Open a console connection to any workstation by right-clicking it and choosing *Console* from the context menu. By default, GNS3 uses *Solar-PuTTY* terminal for the console connection (can be changed from the settings). You can get rid of the pop-up that might appear by entering any bogus e-mail address, for example, a@a.test.

Pick an IP address from your address range and configure it to the workstaton by entering the command `ip addr add ADDRESS/PREFIX dev INTERFACE` to the console. ADDRESS is the IP address in decimal format and PREFIX is the network mask of your subnet in CIDR notation (e.g. /24). INTERFACE is *eth0* in this case.

Choose and add a unique address for every workstation in the same way.

1. In the report, list all IP addresses and network masks you added to the workstations at this point.

Now the workstations have a link layer address (MAC) and a network layer address (IP). You can use the command `ip addr show` to see the addresses.

Start capturing the network traffic on all four links by right-clicking the virtual cables and choosing *Start capture* from the context menu. Default settings are OK. At this point you should have four Wireshark windows open.

Next, use the command (`ping ADDRESS`) in a workstation's console to verify reachability to other workstations. Ping the IP addresses of all other workstations, then answer the following questions:

2. Analyze Wireshark's output from the capture. Which packets are sent by the ping command (i.e. which protocol)?

3. Why are there ARP protocol packets sent right before the ping packets? Which device sends the ARP queries?

4. Why do we need the MAC address to send the packet? In other words, why isn't the IP address enough?

5. Briefly explain how the switch works. Helper questions: On what basis does the switch make forwarding decisions? And what if the switch does not know where the destination address is located?

6. Ping from workstation A to workstation C. In the Wireshark capture on workstation A, inspect a ping packet going **from A to C** and note the IP and MAC addresses included in the packet. Write down the addresses and matching devices in a list or table. A sample is given below.

| | Address | Device |
|---|---|---|
| Source IP | 10.0.X.10 | Workstation A |
| Destination IP | | |
| Source MAC | | |
| Destination MAC | | |

Next, add a second switch to the network. Leave two workstations connected to the first switch and connect two workstations to the second switch as shown in Figure 4. Virtual cables can be removed by choosing *Delete* from the context menu.

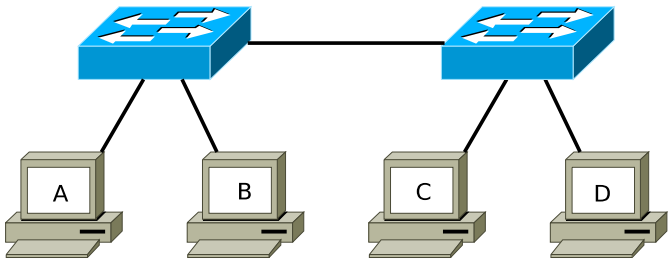


Figure 4: Network topology using two switches

7. Are there any significant changes to the functionality of the network with the adding of the second switch?

# 6 Subnetting

First, let's form smaller subnetworks from your IP address range (10.0.X.0/24) where each of them has to be able to contain 31 devices. Create as small subnetworks as possible.

1. How many addresses are available in the smallest subnetwork that fulfils the criteria?

2. How many different subnetworks that meet the criteria can be formed from your original IP address range? List the network addresses of all possible subnetworks.

3. In the report, write down the requested IP addresses for any two subnetworks that meet the criteria. Use a table or list clearly.

| | Subnet 1 | Subnet 2 |
|---|---|---|
| Network address | | |
| Network mask | | |
| Broadcast address | | |
| First host address | | |
| Last host address | | |

Next, let's put your new subnets into action. Reserve the first host IP of each new subnet for the router and configure suitable new addresses for your workstations. You have to remove the old address first with the command `ip addr del ...` Alternatively, you can restart all workstations using the stop and play buttons at the top of the GNS3 GUI.

Give an IP address from subnet 1 to the workstations connected to the first switch. Give an IP address from subnet 2 to the workstations connected to the second switch.

4. Try to ping between the workstations. Which workstations can connect to each other?

5. Inspect the routing table on a workstation with the command `ip route` . Based on the information given in the routing table, explain why the connection doesn't work between certain workstations.

# 7 Routing

Add a *Cisco router* to the topology from the list of devices. Connect the switches to the router as shown in Figure 5. Remove the cable between the switches. Use the *FastEthernet* interfaces (0/0 and 0/1) in the router. Note which interface is connected to which subnet.

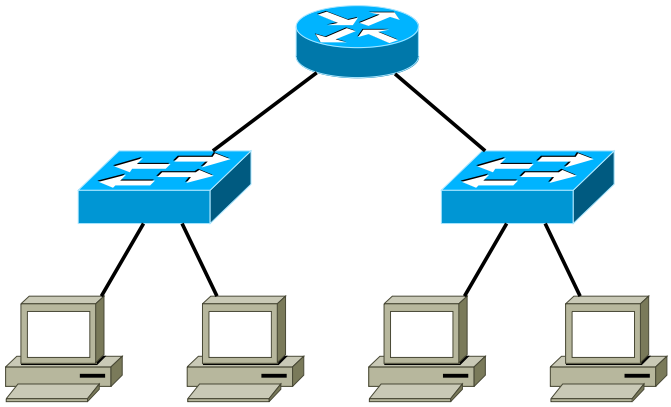

Figure 5: Network topology with the router added

Start up the router and open a console connection to it. In the following commands, X is the number of the interface being configured, ADDRESS and NETMASK are determined by the subnet that is connected to that interface, where ADDRESS is the IP address you want the router to have. Netmask has to be entered in decimal format, e.g. /24 would be 255.255.255.0

```
R1# configure terminal
R1(config)# interface FastEthernet 0/X
R1(config-if)# ip address ADDRESS NETMASK
R1(config-if)# no shutdown
R1(config-if)# exit
R1(config)# interface ...      # repeat for the other interface
```

When the IP addresses of the interfaces are set, you have to set the default gateway on your workstations. Use the appropriate address of the router for the subnet with the command `ip route add default via ADDRESS`.

1. Why is the default gateway needed?

Start network traffic capture on links to workstations A and C. Ping from A to C.

2. The capture on **workstation A** link should show an ARP query just before the ICMP packets. Which device is sending the query, what is being queried and why?

3. Inspect a ping packet going **from A to C** on both captures. Compare the results between the captures and pay attention the IP and MAC addresses included in the packet. What has changed and why? You can optionally include tables here.

# 8 MicroInternet

Congratulations, you have configured a router! Not like the one you have at home, but a real router that is used in large networks. But what is a network without connections to other networks? Exactly. That is your new task.

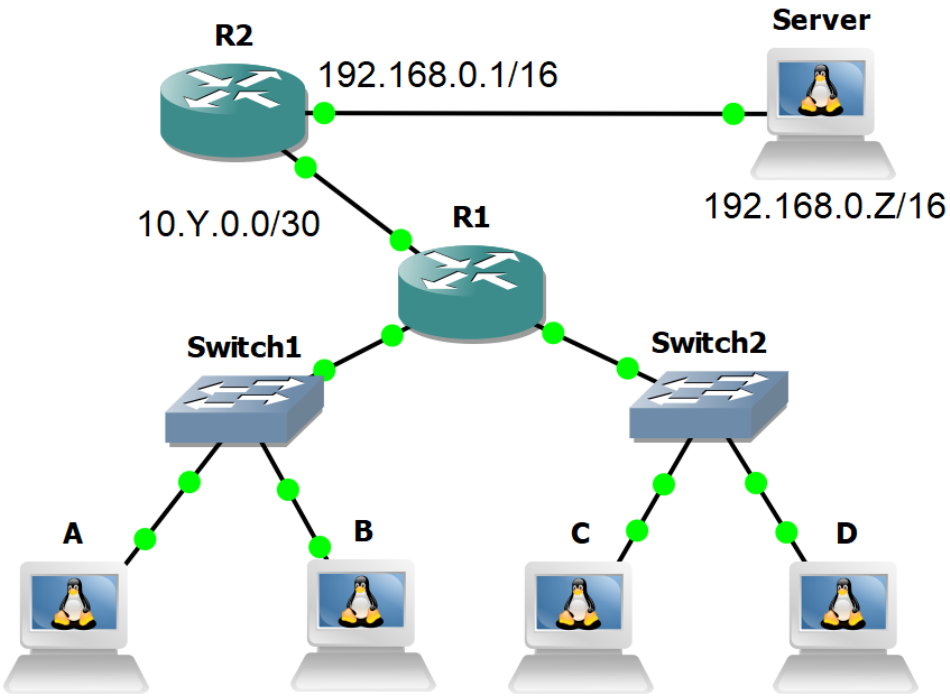


Figure 6: Topology of the mighty MicroInternet

Add a second Cisco router and a Linux workstation to the topology to act as a server as shown in Figure 6. Connect the routers to each other by using the GigabitEthernet 1/0 interface. Note which of R2's FastEthernet interfaces you use to connect to the server.

1. Inspect the routing table of R1 with the command `show ip route` (exit from config mode first with the command *exit*, if necessary). Which networks is R1 now aware of?

2. What happens if a packet with an unknown destination network arrives at the router?
Hint: You can try this in practice by simply pinging an unknown address from a workstation.

Figure 6 tells us that the middle network has the address 10.Y.0.0/30, where Y is the second to last digit of your student number. Add IP addresses from this network to the router interfaces connected to the network.

The IP address of the server is 192.168.0.Z, where Z is the third to last digit of your student number, *plus 2*. The network mask is as shown in the topology (/16). Give an IP address to the interface of R2, which is connected to the server's network. It is practical to use the first device address for the router. Finally, add the IP address the server and set R2 as the default gateway for the server.

3. Which networks is R1 now aware of?

By configuring an IP address to an interface, the router learned which network is connected to that interface. However, the router does not yet know anything about the *Server's* network 192.168.0.0/16 (see Figure 6), so the router needs to be told separately how to connect to that network.

You can add a new route with the following command in router's config mode: `ip route NETWORK NETMASK NEXT_HOP` . NETWORK is the network address of the *destination* network, NETMASK is the network mask of the *destination* network and NEXT_HOP is the address of the next router that hopefully knows the way to NETWORK. Take a look at the example on the last page if this seems difficult.

4. At this point, if you try pinging from a workstation to server, where does the query or reply stop? You can answer either based on theory or Wireshark captures.

   If it seems difficult, try thinking and listing step-by-step what is happening. Consider if each device has information where the packet should be sent next.

5. How should you configure the network so that the ping from a workstation to server works? Implement the configuration. Hint: Adding one thing should be enough.

At this point you should be able to ping from a workstation to the server.

6. From workstation A use the command `traceroute ADDRESS` to inspect the network path to the following devices:

   (a) Workstation B

   (b) Workstation C

   (c) The server

   How many hops are there in each case? How is a hop defined in networking?

   **Note:** the number of lines in the output might not equal to the hop count depending on the used definition.

# 9 Saving the configurations

Configurations of all seven devices **must** be submitted along with the report. Additionally, please note that all GNS3 projects will be deleted after the course is over, so take backups if you need them.

## 9.1 Cisco router

Option 1: Enter the command `show running-config` to the router's console (exit config mode first if necessary) and copy the output into a text file.

Option 2: Enter the command `write memory` to the router's console (exit config mode first if necessary). This configuration also saves the configuration that it does not disappear when you close the device/project. After a while you can *Export config* from the router's context menu (startup-config is enough). Make sure that the config has synced by checking the contents of the exported file!

## 9.2 Linux workstation

Enter the commands `ip addr show` and `ip route show`. Copy the output to a text file or take a screenshot.

To save the IP addresses more permanently, edit the file */etc/network/interfaces* with a text editor (e.g. *vi* or *nano*), so that the IP addresses and gateways will be set automatically during boot. Example:

```
auto eth0
iface eth0 inet static
        address 192.168.0.2
        netmask 255.255.255.0
        gateway 192.168.0.1
```

# 10 Common problems

**The router gives an error "Bad mask /## for address #.#.#.#" when trying to set an IP address to an interface.**

You are likely trying to set either a network address or a broadcast address to the interface (such as 10.0.0.0/24 or 10.0.0.255/24). The network address is only used to identify the network, and such cannot be used by any device.

**The concept of adding a route to a router is not very clear to me.**

In Cisco routers, you can add a new route with the following command in config mode: `ip route NETWORK NETMASK NEXT_HOP` . NETWORK is the network address of the *destination* network, NETMASK is the network mask of the *destination* network and NEXT_HOP is the address of the next router that hopefully knows the way to NETWORK. Example case:

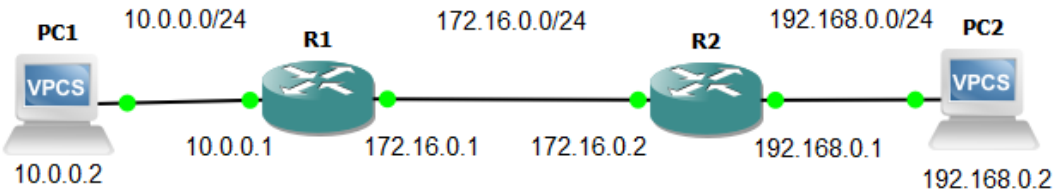


Figure 7: A simple network

In the situation pictured in Figure 7, the router R1 is aware of networks 10.0.0.0/24 and 172.16.0.0/24 because it is directly connected to them. When configuring the interfaces 10.0.0.1 and 172.16.0.1, the network mask has also been set, which tells the router the network this interface belongs to.

However, R1 does not know anything about the network 192.168.0.0/24, so we have to tell it how to reach the network by entering the command `ip route 192.168.0.0 255.255.255.0 172.16.0.2` This command basically tells the router that if a packet is going to the network 192.168.0.0/24, send it forward to the router with the IP address 172.16.0.2.

**Wireshark gives the error message "End of file on pipe magic during open" when starting a capture.**

One possible cause for this is that the path to your TEMP folder contains non-ASCII characters (such as *ääöé*). In Windows, the default path includes your username, so if your username contains these characters, it might be causing this issue. Two solutions are known:

1. Create a new user with a simple name that doesn't contain these characters.

2. Change the TEMP environment variable (*ympäristömuuttuja* in Finnish) to a path with only ASCII characters, such as C:\Temp.

Simply rebooting your computer has also helped in at least one case. Remember to save your configurations before closing the project!